# Complications of Robot-Assisted Radical Prostatectomy

36

Russell S. Terry, Mohit Gupta, and Li-Ming Su

**Abstract**

Robotic surgery represents a shift in the surgical paradigm and is consequently associated with a unique set of challenges and complications in comparison to open or conventional laparoscopic surgery. For the first time, the surgeon is not directly at the bedside but is rather directing an intermediary machine and a separate bedside team to perform the operation. This, in addition to the lack of tactile feedback, the greater reliance on visual anatomic clues when performing robotic surgery, and the inherent risk of malfunction or mechanical failure of robotic components may all contribute to complications noted during robot-assisted radical prostatectomy (RARP). In this chapter, we outline the risks and incidence of the more common complications associated with RARP and present methods to manage them.

**Keywords**

Radical prostatectomy · Robotic surgery · Complications · Prostate cancer

R. S. Terry · M. Gupta · L.-M. Su (✉)
Department of Urology, University of Florida College of Medicine, Gainesville, FL, USA
e-mail: Russell.terry@urology.ufl.edu; mohit.gupta@urology.ufl.edu; Li-ming.su@urology.ufl.edu

## Introduction

Since the approval of the first robotic surgery system by US Food and Drug Administration in 2000, there has been a significant increase in the use of robot-assisted surgery. Robotic technology has been rapidly adopted as part of modern surgical practice and has been embraced by the urologic community in particular. While urologic applications of the technology include robot-assisted pyeloplasty, cystectomy, and partial nephrectomies, the robotic system's largest impact has been in its use for radical prostatectomy. Recent data has shown that utilization of robot-assisted radical prostatectomy (RARP) increased from 1.8% in 2003 to 85% in 2013 [1]. Given the lower morbidity in comparison to open surgery and increasing inter-hospital competition to offer the latest technology to patients, robotic surgery is expected to remain widely utilized [2].

Robotic surgery represents a shift in the surgical paradigm and is consequently associated with a unique set of challenges and complications in comparison to open or traditional laparoscopic surgery. For the first time, the surgeon is not directly at the bedside but is rather directing an intermediary machine and a separate bedside team to perform the operation. Advantages to the robotic interface include the visualization benefits of laparoscopic surgery plus three-dimensional magnified vision, six degrees of surgical freedom, and enhanced tremor filtration


A. K. Hemal, M. Menon (eds.), *Robotics in Genitourinary Surgery*,
https://doi.org/10.1007/978-3-319-20645-5_36

[3]. Disadvantages unique to the robotic approach include a lack of tactile feedback compared to open and traditional laparoscopic approaches as well as the inherent risk of malfunction or mechanical failure of robotic components.

In this chapter, we outline the risks of complications associated with RARP and suggest methods to manage them. An overview of the most common complications of RARP from large published series and meta-analyses is provided in Table 36.1. We have also identified specific instances when complications may occur and provide suggestions to minimize them. It is essential for the surgeon to understand these complications prior to undertaking an operation in order to prevent them from occurring, to direct the surgical team towards safe troubleshooting of complications when they do occur, and to recognize and treat them swiftly. The importance of having an experienced surgical team that understands and is ready to manage perioperative complications cannot be overemphasized.

## Overall Complications: Robotic vs Open Approach

Despite the rapid adoption of RARP, no large-scale randomized controlled trials have demonstrated its superiority over open radical prostatectomy (ORP) with regards to complications [1, 4, 5]. There is, however, a growing body of evidence suggesting that robotic prostatectomies may be associated with lower complication rates, although the majority of such evidence so far has largely come from observational cohort studies and meta-analyses [6, 7].

The complication rates of ORP reported from centers of excellence are low and range from 6% to 10% [8, 9]. Encouragingly, multiple comparative studies have demonstrated significantly fewer 30-day complications, blood transfusions, anastomotic strictures, decreased postoperative pain and shorter length of stay (LOS) in RARP compared to ORP [10, 11]. A recent comparative study of 5915 Medicare patients treated with either ORP or RARP between 2008 and 2009 found no differences in complications, readmissions, or additional cancer therapies, however a significant benefit with regard to blood transfusions and length of stay (LOS) was identified [12]. Another population-based study over the same time period with 19,462 patients of all age groups and insurance statuses found significant decrease in transfusion rate, LOS, intraoperative and postoperative complications for RARP compared to ORP [13]. A recently published population-based study between 2003 and 2013 with over 600,000 patients demonstrated lower 90 day postoperative complication rates including blood transfusion rates and shorter LOS for patients undergoing RARP, even among patients with multiple comorbidities [1]. The overall complication rate for RARP is approximately 9% based on a recent systematic review and meta-analysis of over 100 published studies, and almost 80% of these complications were considered low grade (Clavien-Dindo I or II) [7].

An additional factor that must be considered in the modern healthcare environment is the contribution of cost to the delivery of surgical treatments. The most recent large database cohort study of ORP versus RARP revealed the mean 90 day direct hospital costs of RARP to be approximately $4500 higher than for ORP, although this cost difference was noted to lose significance when comparing only high-volume surgeons [1]. A follow up study to this one examining surgeon and hospital-level RARP cost variation in more detail demonstrated that high-volume surgeons and hospitals were associated with increased odds of a lower-cost RARP [14].

## Complications Related to Patient Positioning

Appropriate and safe positioning of the patient on the operating table is critical to the success of the operation, and the two primary considerations in this regard are adequate exposure of the operating field as well as prevention of positioning-related injuries. After induction of general endotracheal anesthesia, the patient's arms and hands should be carefully tucked and padded at the sides with egg-crate padding to avoid injury

**Table 36.1** Overview of RARP complications from prior large series and meta-analyses

| Authors | Year | Patients (N) | Thromboembolic complication incidence (%) | Transfusion rate (%) | Bowel injury incidence (%) | Ileus incidence (%) | Lymphocele incidence (%) | Urine leak incidence (%) | Anastomotic contracture incidence (%) | Overall complication rate (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Hu et al. [30] | 2006 | 322 | | 1.6 | | 2.8 | 0.9 | 7.5 | 0.6 | 15 |
| Fischer et al. [46] | 2008 | 210 | | 1 | 1.5 | | 0.5 | | 0.5 | 26.1 |
| Coelho et al. [47] | 2010 | 2500 | 0.52 | 0.48 | 0.08 | 0.72 | 0.36 | 1.4 | 0.12 | 5 |
| Siddiqui et al. [17] | 2010 | 4000 | 0.3 | 1.9 | 0.5 | 0.7 | 0.2 | 0.7 | | 5 |
| Novara et al. [7] | 2012 | Meta-analysis of 110 studies | 0.2 | 2 | 0.2 | | 3.1 | 1.8 | | 9 |

to the median and ulnar nerves and subsequent upper extremity palsies. Deliberate padding of vulnerable bony prominences such as the hips, shoulders, knees, and calves is important to prevent pressure injuries and neuromuscular complications. Because the patient's arms will be tucked at the side and difficult to access intraoperatively, it is critical to work with the anesthesia and nursing teams to ensure accurate pulse oximetry, blood pressure cuff placement, and intravenous access are established prior to beginning the case and that these processes do not become compromised during the positioning process.

The patient's legs should be placed in lithotomy stirrups or secured on a split-leg table with egg-crate padding and tape, and abducted slightly in order to allow intraoperative access to the rectum and perineum by the bedside assistant as necessary. The authors prefer the use of a split-leg table as this provides broad and uniform support of the lower extremities. Sequential compression devices should additionally be utilized to reduce the risk of deep venous thrombosis. Extension at the hip should be kept to the minimum necessary so as to allow successful docking of the robotic arms; over-extension may lead to postoperative lower extremity neuropraxia. Patients are at unique risks for specific lower extremity neuropathies secondary to the steep Trendelenburg positioning with hip extension, especially following prolonged surgeries [15]. The frequency of these lower extremity neuropathies appears to be low (1.3%) and predominantly transient in nature. Exaggerated extension of the operating table at the level of the hips while docking the robotic arms may increase the risk for femoral neuropraxia. The etiology of this injury is thought to be secondary to either stretch injury or compression of the femoral nerve as it courses beneath the inguinal ligament with resultant transient motor and sensory neuropathy. Presenting symptoms of femoral neuropraxia include anterior thigh numbness and quadriceps muscle weakness, and when present the patient will generally begin displaying symptoms soon after waking from surgery.

Once appropriately positioned, the patient is then secured firmly to the table using 3 in. heavy cloth tape and egg-crate padding across the chest or in a criss-cross fashion to help prevent the patient from sliding cephalad while in the steep Trendelenburg position during the operation. Fixed shoulder rests should be avoided altogether as these devices can result in compression injury to the shoulder joints, muscles, and brachial plexus when in prolonged steep Trendelenburg. An orogastric tube should be placed to decompress the stomach prior to trocar access, and a foley catheter should be placed under sterile conditions so that it may be accessed during the procedure.

## Anesthesia-Related Complications

The primary anesthetic considerations during RARP relate to physiological changes in the cardiopulmonary, ocular, and intracranial systems that occur in the steep Trendelenburg position in the setting of $CO_2$ pneumoperitoneum especially during prolonged surgeries [16].

Sinus bradycardia can be observed and is likely attributable to increased abdominal pressure from pneumoperitoneum producing a vagal response from stretching of the peritoneal structures. This can often be managed successfully with prompt desufflation of the abdomen and administration of atropine [17]. More commonly, sinus tachycardia is observed which is thought to be secondary to pharmacologic sympathetic stimulation by increased arterial $pCO_2$ as well as a compensatory mechanism for the decreased cardiac return of blood flow during periods of elevated intraabdominal pressure.

Assessment of volume status is particularly challenging during RARP given that much of the patient's urine output will be draining into the operative field during the case, and the elevated intraabdominal pressure can additionally cause an independent decrease in urine output and glomerular filtration rate [18]. Excessive hydration during the case leading to increased urine output can be detrimental as it can obscure the operative field and make the anastomosis more challenging to perform. Fluid overload in a steep Trendelenburg position can also cause significant facial edema, especially early in the surgeon's learning curve when operative times may be lengthy [17]. For these reasons, consideration should be given to limiting intravenous fluid administration to approximately two liters of crystalloid solution in healthy patients and even smaller volumes in patients with baseline cardiovascular or renal dysfunction.

The steep Trendelenburg position, particularly in the setting of pneumoperitoneum, has also been associated with temporary increases in intraocular pressure, which seem to resolve upon return to the supine position [19]. Amongst other potential causes, the two operative variables which have been identified to contribute significantly to this effect are operative time and hypercarbia. Mechanistically, it is thought that elevated central venous and ocular venous pressure secondary to the steep Trendelenburg position is exacerbated with prolonged operative time. This effect is further aggravated by choroidal vasodilation secondary to increased arterial $pCO_2$ resulting from the pneumoperitoneum. While the clinical relevance of this transient phenomenon is unclear and its effects are generally unapparent in the majority of healthy individuals, it may pose particular concern in elderly patients who have elevated intraocular pressures at baseline, such as glaucoma patients. It is unknown whether this effect is causally associated with the rare reports of acute visual loss following minimally invasive prostatectomy as a result of posterior ischemic optic neuropathy [20]. Nevertheless, it is advisable that both surgeon and anesthesiologist inquire about preexisting ocular disease in the preoperative screening of patients who select to undergo RARP. Furthermore, it is strongly advised to keep operative times as short as possible as many of these anesthesia or positioning complications are more common with prolonged surgery. The additional potential ophthalmologic complication of corneal abrasion, which is generally of limited long-term significance but can cause significant pain in the recovery period, is easily prevented with adequate eye lubrication and protection maintained during the procedure and early recovery room period.

Both steep Trendelenburg positioning and establishment of pneumoperitoneum cause increased intracranial pressure (ICP). The clinical endpoint of cerebral perfusion, however, is generally not compromised as $CO_2$ mediated vasodilation and increased mean arterial pressure have been shown to keep cerebral perfusion pressure above the autoregulation threshold. Special consideration should be taken when operating on patients with known intracranial pathology who may not be able to autoregulate their cerebral perfusion pressure as efficiently. Special care should also be taken in patients with ventriculoperitoneal shunts, as the expected increases in abdominal pressure from pneumoperitoneum and ICP from the positioning may change the flow dynamics within the shunt, and for this reason preoperative neurosurgical consultation should be considered in patients with shunts who are undergoing RARP.

Throughout the case, it is imperative that the surgeon and anesthesiologist maintain continuous awareness of the patient's end-tidal $CO_2$ level and intraabdominal insufflation pressure as the potential consequences of prolonged pneumoperitoneum and hypercarbia including oliguria, acidosis, and decreased cardiac output can be significant. Prompt adjustments in minute ventilation may be required by the anesthesiologist in the event of rising end-tidal $CO_2$ levels or worsening hypercarbia on repeated arterial blood gas testing [21]. Adjustments in $CO_2$ insufflation pressures may also be required by the surgeon to reduce the risks associated with prolonged hypercarbia. The authors generally recommend maintaining insufflation pressures between 12 and 15 mm Hg. When left untreated, prolonged hypercarbia can progress to life threatening systemic acidosis and multiple organ system dysfunction, and should therefore be minimized.

## Access-Related Complications

### Vascular and Bowel Injuries

Deliberate and safe access into the peritoneal cavity and trocar placement is an essential element of performing successful RARP. Though a seemingly minute part of the greater procedure, this task is not without risk, and reports estimate an access injury incidence of between 5 and 30 per 10,000 cases [22], the vast majority of which are either vascular or bowel injuries. There are numerous methods by which attainment of pneumoperitoneum and placement of trocars can be achieved. Commonly, a Veress is used to access the peritoneal cavity quickly and initiate pneumoperitoneum, followed by placement of the first trocar under direct vision using an optical trocar and 0° lens. Generally, the umbilicus is used as the insertion site for the Veress, however care should be taken to avoid placing the Veress through a prior abdominal scar due to the risk of adhesions and subsequent accidental puncture of intra-abdominal organs. Sharp or bladed trocars should be avoided. Prior to insufflation, a syringe should be used to draw back on the Veress and ensure that there is no return of either blood or visceral contents, and a drop test should be performed to confirm appropriate placement. Once satisfied with the needle position, insufflation with $CO_2$ may proceed. The insufflator should be closely monitored to ensure low intraabdominal pressure (4–6 mmHg) with good $CO_2$ flow initially, which again reassures that the needle is in the appropriate position. Alternatively, if there is heightened concern for the presence of adhesions based on the patient's surgical history, the Hasson technique can be utilized [23]. Ultimately the optimal choice of access technique is the one in which the surgeon is the best trained and most comfortable.

The mean incidence of vascular injury during laparoscopic access is less than 0.05% [24]. Although rare, the outcomes can be devastating, with one series reporting a 44% mortality rate for major visceral vessel injury sustained during laparoscopic access. The most commonly injured vessels during pelvic laparoscopy are the aorta and the common iliac arteries [25]. Rarely a major mesenteric vessel can be involved if it is trapped within an adherent loop of bowel near the site of access and is punctured. Signs of significant vascular injury include profuse bleeding from trocar sheath, rapidly accumulating blood within the abdominal cavity or an expanding retroperitoneal hematoma, and hypotension with associated tachycardia. Once identified, rapid management must ensue with laparotomy if necessary, identification of the bleeding vessel, and primary repair. Less significant vascular injuries in which visualization and the patient's hemodynamics are not compromised may be managed laparoscopically. Abdominal wall vessels are also at risk during trocar placement, namely the inferior epigastric arteries that lie within the lateral rectus sheath and may be compromised during para-rectus trocar placement. This injury is often recognized when blood is noted to be dripping down from the trocar sheath into the abdomen, or at the end of the case when the trocar is removed under direct vision. When apparent, care should be taken to ensure vessel ligation or, when that is not possible, a Carter-Thomason device can be used to broadly pass a suture around the terminal ends of the vessel and secured to tamponade the bleeding [26]. The use of abdominal transillumination to clearly visualize the epigastric vessels and their branches in addition to the use of blunt instead of bladed trocars has been shown to decrease the risk of significant abdominal wall bleeding [27].

Small and large bowel are also at risk during laparoscopic abdominal access, and the incidence of bowel injury as a complication of laparoscopy has been reported to be 0.22%. Approximately 40% of those injuries occur during access [28]. Like vascular injuries, the surgeon may elect to perform laparoscopic primary repair with multiple layer closure for less significant injuries, and open repair may be necessary for more significant injuries. In either case, general surgery consultation at the time of injury recognition is advisable.

Based on the risks inherent to accessing the abdomen and placing trocars, it is prudent to visually inspect all trocar sites and underlying abdominal contents following access. This quick and simple maneuver will allow early identification and treatment of any potential injuries which, if left untreated or unrecognized, could increase exponentially in conferred morbidity or mortality to the patient in the postoperative setting. Once safe trocar placement is established and the robot has been docked, care must be taken throughout the operation to avoid injury along the path of the multiple instruments, which typically must be interchanged and directed toward the pelvis numerous times throughout the course of the operation. The guided-instrument exchange function of the robot should be utilized with each instrument exchange performed by the bedside assistant in order to minimize the potential for injury and complications from blind passage or "past-pointing" of the instrument tip.

### Gas Embolism

In additional to the sequelae of blood loss following a vascular injury during access, gas embolism represents a rare but potentially fatal complication which occurs when a blood vessel is punctured by the Veress needle and insufflated during access. The presentation of gas embolism is acute cardiovascular decompensation characterized by bradycardia, hypotension, and a sudden drop in end-tidal $CO_2$ followed by declining oxygen saturation. When suspected, the treatment is immediate desufflation of the abdomen, transfer to the left lateral decubitus Trendelenburg position, and hyperventilation with 100% oxygen administration. A central line can be placed to attempt to aspirate the gas from the right atrium. This complication is highly preventable through the use of the aspiration and drop tests described previously, which, if performed, would identify intravascular placement of the Veress needle and allow correction prior to $CO_2$ insufflation.

## Intraoperative Complications

### Rectal Injury

Rectal injuries are relatively uncommon during RARP (0.1–1.25%) [29–31]. There are numerous identifiable risk factors that may predispose patients to rectal injury, including: prior abdominal or pelvic surgery (e.g., TURP), history of diverticulitis, history of prior pelvic radiation, or locally invasive cancer. These injuries have been reported to be managed successfully by laparoscopic means in several series [32–34]. Intraoperative recognition and repair of the injury is of paramount importance. Multilayered primary closure with or without interposition of omentum between the rectum and anastomosis and copious irrigation can usually prevent long-term problems and ensure good healing in the majority of patients. In cases where there is a significant injury with fecal spillage or in patients who have been radiated or otherwise have factors for poor wound healing (i.e., chronic steroid use, immunosuppression), intraoperative colorectal consultation is advisable for consideration of more extensive repair or potential intestinal diversion. Inadequate closure or lack of recognition can result in devastating complications, such as rectourethral fistula or peritonitis. If a small rectal injury is suspected but not readily visible, insufflation of air into the rectum using a catheter inserted into the rectum with fluid within the pelvis (i.e. air bubble test) can often be used to localize an otherwise undetectable injury. In the authors' experience, rectal injury occurs most commonly during the distal-most extent of the posterior dissection near the apex, where visualization is more likely to be compromised. In efforts to minimize rectal injury, dissection should be taken as close to the prostatic surface as possible when performing the posterior dissection of the prostate, maintaining awareness that the rectum may be tented up to the prostate due to prior biopsies, infections, or fibrosis.

### Ureteral Injury and Obstruction

Rare and uncommonly reported in large series, ureteral injury during RARP may occur during the posterior dissection where it is misidentified as the vas deferens, or during extended lymphadenectomy where the ureter crosses over the iliac vessels. If recognized intraoperatively, a minor injury may be treated with primary repair and stent placement. A more significant injury may require uretero-ureterostomy or re-implantation.

A more common scenario, particularly in patients with large median lobes, are ureteral orifices which fall close to the level of the posterior bladder neck transection and are therefore at risk of becoming obstructed by the anastomosis or even by the foley catheter balloon. This classically presents postoperatively with rising creatinine and ipsilateral flank pain. When suspicion is aroused that a ureteral orifice may be obstructed in the post-operative period, CT-urogram can be helpful in identifying hydronephrosis or other potential sources of the problem. If the imaging study correlates clinical concern for ureteral obstruction, a reasonable first step is partial deflation of the foley catheter balloon with simultaneous gentle advancement of the catheter a few centimeters, securing it in its new location, and serial serum creatinine monitoring to assess for improvement. If no improvement is noted, consideration should be given to percutaneous nephrostomy placement followed by antegrade nephrostogram once the foley catheter is removed. If the obstruction is due to edema at the anastomosis or as a result of obstruction by the foley balloon, this often will resolve once the foley is removed. A direct ureteral injury on the other hand may require endoscopic or open surgical repair.

Ultimately, obstruction of ureteral orifices that are located at the edge of the posterior bladder neck margin can be minimized by imbrication of the ureteral orifices using interrupted sutures at the 3 and 9 o'clock position prior to completion of the anastomosis [35]. Otherwise, ureteral stents may be placed temporarily and later removed once the anastomosis is well healed.

## Obturator Nerve Injury

During pelvic lymph node dissection, the obturator nerve can be at risk for injury due to poor visualization of its anatomic course. Clinical presentation of such an injury is generally characterized by weakness of thigh adductors in the postoperative period. Prospective identification of the obturator nerve and dissection of the lymph nodes away from the nerve can aid in preventing inadvertent thermal injury, transection, or mechanical injury from a hemoclip. In cases when obturator nerve injury occurs, successful repair with perineural nerve sheath reapproximation has been described with good functional outcomes [30, 36].

## Intraoperative Bleeding and Transfusion

Virtually all published reports have documented a distinct advantage for laparoscopic and robotic surgery in diminishing the amount of bleeding that occurs during radical prostatectomy. Transfusion requirements of 2% or less are commonly reported [37]. The tamponade effect of the pneumoperitoneum compresses venous bleeding intraoperatively, and the superior visualization within the deep pelvis allows timely identification of bleeding vessels that require precise hemostasis. Both of these factors represent significant advantages over the open surgical approach. However, despite these distinct advantages, there is the possibility of postoperative bleeding which becomes unmasked once pneumoperitoneum is relieved. For this reason, the pelvis and surgical field should be carefully inspected for the presence of bleeding at the end of the operation under low insufflation pressure.

## Equipment Malfunction

The surgeon is highly dependent on sophisticated technology and equipment for performance of RARP. Equipment malfunction, especially with RARP, can create problems that make it impossible to progress with surgery and may result in case cancellation or conversion to conventional laparoscopic or open surgery. One review of >8000 robotic cases found a 0.4% nonrecoverable malfunction rate in their multi-institutional study of high-volume RARP centers [3]. Within this group of cases, 70% of the errors were able to be identified prior to the start of the procedure and the majority were recoverable errors. Although extremely rare, patients need to be properly counseled about the possibility of conversion to a conventional laparoscopic or open surgical approach in the event of an unrecoverable equipment malfunction.

### Open Conversion

Open conversion is rare (<2%) and has been cited in the literature, usually during a surgeon's early experience with RARP, typically as a result of failure to progress or uncertainty of dissection planes [38]. Occasionally, as noted previously, open conversion is required for the management of significant vascular or gastrointestinal injury. The key to minimizing the need for open conversion starts with proper patient selection. Novice robotic surgeons are best advised to avoid patients with large prostate glands >75 g, obesity, prior prostate or lower pelvic surgery, or previous radiation or androgen ablation therapy at least early in their experience. With increasing surgeon experience, however, the need for open conversion is rare. Nonetheless, patients must be properly counseled regarding the potential necessity of open conversion with this or any minimally invasive operation.

## Postoperative Complications

### Postoperative Bleeding

Although rare, postoperative hemorrhage must be considered in the patient with hypotension and worsening blood count parameters after surgery. When this occurs, these patients should be placed on bed rest and transfused as necessary. Should their parameters continue to decline, prompt surgical re-exploration should be considered earlier rather than later as the presence of a pelvic hematoma can lead to partial disruption of the vesicourethral anastomosis, a prolonged hospital course, and catheterization with potential scarring leading to a bladder neck contracture [38]. It is reasonable to perform re-exploration robotically using the same sites as the original operation.

### Thromboembolic Complications

The 2008 American Urological Association Best Practices Statement recommends the routine use of intermittent pneumatic compression devices for laparoscopic and robotic urologic procedures. However, it does not recommend routine use of prophylactic anticoagulants for these procedures unless a patient has multiple known risk factors such as obesity, advanced age, malignancy, immobility or a prior history of deep venous thrombosis (DVT). Nonetheless, because of the known venous stasis and hypercoagulable state that can occur during pelvic surgery in patients with known malignancy, RARP patients are considered to be at risk for thromboembolic complications. Performance of pelvic lymph node dissection (PLND) during RARP appears to increase this risk, with one study reporting a 2.6% incidence of DVT or pulmonary embolism (PE) following RARP with PLND versus a 0.4% incidence following RARP alone [39]. Additionally, the incidence of mortality associated with such a complication following RARP has been recently reported to be approximately 3%, thus justifying efforts to minimize its occurrence [39]. Based in part on this apparent paradox between professional guidelines recommending no pharmacologic prophylaxis and surgeons' desire to avoid this morbid and mortal complication in their patients, the issue of DVT prophylaxis in the RARP perioperative period has been identified as an area with high priority need for research by at least one expert panel [40]. With respect to DVT prophylaxis, the authors utilize only pneumatic compression devices in the perioperative period following RARP with instructions to ambulate early in the postoperative setting. Anticoagulants are used primarily in patients with a history of thromboembolic events or who are debilitated and physically compromised such that early ambulation is not possible.

The low overall incidence of thromboembolic complications after RARP has been is perhaps due in part to Trendelenburg positioning and quicker postoperative patient mobilization following a robotic procedure. Both of these factors decrease venous stasis in the lower extremities as compared to open surgery [41]. Factors which have been identified to increase risk of thromboembolic events following RARP include a history of thrombosis, pT4 stage, Gleason score of 8 or higher, and performance of lymph node dissection [39]. The clinical presentation of DVT in the lower extremities in the postoperative period should prompt immediate diagnostic evaluation with Doppler ultrasound, consideration of obtaining a pelvic CT scan to exclude a lymphocele, hematoma, or urinoma that could be compressing the external iliac vein contributing to lower extremity venous stasis, and prompt anticoagulation if deemed necessary. If respiratory symptoms such as dyspnea, pleurisy, hypoxia, or chest pain are also present and the suspicion of a pulmonary embolus is high, prompt administration of systemic anticoagulation followed by contrasted chest CT scan or ventilation-perfusion scan is strongly advised.

## Ileus and Unrecognized Bowel Injury

Transient postoperative ileus following RARP is not uncommon, however prolonged ileus is an uncommon event that typically occurs in 0.7–2.8% of patients [2, 29–31]. The exact pathogenesis of ileus is multifactorial and complex, and the body's response to surgical stress can lead to disorganized electrical activity and paralysis of intestinal segments. Physiologic ileus following RARP usually spontaneously resolves within 2–3 days after RARP, and patients are best managed with bowel rest and gastric decompression, if indicated. Prolonged adynamic ileus may occur secondary to a pelvic hematoma or urinary ascites and should prompt the surgeon to pursue further diagnostic evaluation and treatment.

Unrecognized bowel injury which goes unrepaired at the time of surgery can be one of the most serious potential complications of RARP or of any minimally invasive surgery. Injury to small bowel segments has also been reported between 0% and 0.7% [29–31]. Injuries may occur while obtaining access (i.e., trocar-related injury), during enterolysis of adhesions secondary to prior abdominal surgeries or inflammatory processes, or due to thermal spread during use of electrocautery. In particular, inadvertent use of monopolar electrocautery may cause thermal injury to surrounding viscera. In addition, micropunctures in the insulating sheath around the monopolar scissors can result in electrical arcing and thermal injury to nearby structures such as bowel. As such, the insulating sheath should be replaced if overt tears are noted. These injuries, when they occur, may be subtle and go unnoticed, presenting in a delayed fashion with low grade fevers and mild abdominal tenderness but occasionally with persistent bowel activity [2]. Early recognition of bowel complications is particularly important as patients may rapidly deteriorate clinically secondary to sepsis. Abdominal CT scan with oral and intravenous contrast is the diagnostic test of choice. A discussion of the management of bowel injuries noted intraoperatively is discussed above.

## Lymphocele

A common complication related to PLND is lymphocele due to disruption of lymphatic vessels. The published incidence of post-operative lymphocele following RARP with PLND ranges between 30.4% and 51%, and these numbers vary widely depending on both postoperative imaging modality (CT versus ultrasound) as well as imaging time interval after surgery. Despite the high reported incidence, it has been reported that only 15.4% of these lymphoceles become symptomatic, corresponding to 7% of all patients who undergo RARP with PLND [42]. The incidence of postoperative lymphocele has also been shown to be dependent on the extent of lymph node dissection [43]. Patients with symptomatic lymphocele typically present with complaints of pelvic pressure, abdominal distention, worsening lower urinary tract symptoms, or lower extremity edema. Should the lymphocele become progressively symptomatic or infected, percutaneous drainage is often required. Postoperative lymphoceles are best minimized by judicious use of hemoclips to ligate any divided lymphatic vessels. Mechanical ligation with hemoclips is superior to any thermal device in securing lymphatics.

## Anastomotic Complications

A urinary leak is one of the most feared post-operative complications which can occur following RARP. As mentioned previously, a postoperative pelvic hematoma can cause partial disruption of the anastomosis. Failure to achieve a tension-free, watertight approximation of the anastomosis can result in urinary extravasation This can be even more problematic with a transperitoneal (vs. extraperitoneal) surgical approach because the entire abdominal cavity is accessible for urine egress. The output of increased volume of clear fluid from the surgical drain will often alert a surgeon to the presence of potential urinary extravasation and should trigger evaluation for this problem, as detailed below:

1. The first and simplest step in the diagnostic process is to perform gentle bedside catheter irrigation of the patient's foley catheter to confirm good placement within the bladder and to rule out any element of clot obstruction.
2. Next, if the drainage persists, a sample of the drain output should be sent for creatinine analysis. A creatinine value at or near the serum measurement is reassuring that the fluid represents serous fluid only. An elevated creatinine above the serum value confirms a urine leak.
3. At this point, with elevated drain output of high-creatinine fluid, imaging can be performed but is often not necessary. Withdrawing the pelvic drain away from the anastomosis and placing it to gravity (vs. bulb suction) is advised to encourage urine egress through the foley and not out of the drain. If there is any element of concern for possible ureteral injury as a result of the procedure, consideration should be given to comprehensive assessment of upper tracts with a CT-urogram.
4. Most small anastomotic leaks will resolve spontaneously with prolonged urethral catheter drainage, and these patients may be reevaluated in 10–14 days as an outpatient with resolution cystogram. A large leak may require catheterization for up to a month or possibly longer to completely heal. If complete disruption of the anastomosis has occurred, surgical revision is indicated, even within the first few days after surgery.

Aside from causing elevated drain output and prolonged catheterization for the patient, a significant urine leak has the potential to cause chemical peritonitis which may lead to postoperative ileus. If imaging reveals incomplete drainage of abdominal fluid in the setting of urinary ascites or peritonitis, consideration should be given for placement of an additional percutaneous drain which would function to better drain the problematic fluid accumulation and decrease the risk of additional downstream problems, such as abscess or fistula formation.

Anastomotic stricture resulting in bladder neck contracture is another potential complication following prostatectomy, although it seemingly occurs at a lower rate after RARP compared with open surgical approaches, especially in the hands of experienced surgeons. Rates of less than 2% have been reported [44, 45]. Again, achievement of a tension-free, watertight anastomosis with good mucosal approximation is a key measure in preventing anastomotic leaks and postoperative bladder neck contracture.

Lastly, "erosion" of hemoclips into the lumen of the bladder at the anastomosis can rarely occur. Patients may present with new onset obstructive voiding symptoms, gross hematuria or urinary tract infections prompting cystoscopy which identifies a hemoclip partially protruding into the lumen of the bladder at the anastomosis. This likely occurs due to partial disruption of the anastomosis by hemoclips that have been placed near the anastomosis. As such it is advised to minimize placement of hemoclips at or near the anastomosis at the time of surgery when possible. Once identified, these hemoclips can be removed cystoscopically under anesthesia. Titanium clips are relatively easy to remove, whereas Hem-o-lok polymer clips may require the use of a holmium laser to divide "unlock" the two arms of the clip to facilitate removal.

## References

1. Leow JJ, Chang SL, Meyer CP, Wang Y, Hanske J, Sammon JD, et al. Robot-assisted versus open radical prostatectomy: a contemporary analysis of an all-payer discharge database. Eur Urol. 2016. [Epub ahead of print];70:837.

2. Coelho RF, Palmer KJ, Noguera RJS, Patel VR. Prevention and management of complications during robotic-assisted laparoscopic radical prostatectomy. In: Patel VR, editor. Robotic urologic surgery. 2nd ed. London: Springer; 2012. p. 231–45.
3. Lavery HJ, Thaly R, Albala D, Ahlering T, Shalhav A, Lee D, et al. Robotic equipment malfunction during robotic prostatectomy: a multi-institutional study. J Endourol. 2008;22(9):2165–8.
4. Gardiner RA, Coughlin GD, Yaxley JW, Dunglison NT, Occhipinti S, Younie SJ, et al. A progress report on a prospective randomised trial of open and robotic prostatectomy. Eur Urol. 2014;65(3):512–5.
5. Wallerstedt A, Tyritzis SI, Thorsteinsdottir T, Carlsson S, Stranne J, Gustafsson O, et al. Short-term results after robot-assisted laparoscopic radical prostatectomy compared to open radical prostatectomy. Eur Urol. 2015;67(4):660–70.
6. Hu JC, Gu X, Lipsitz SR, Barry MJ, D'Amico AV, Weinberg AC, et al. Comparative effectiveness of minimally invasive vs open radical prostatectomy. JAMA. 2009;302(14):1557–64.
7. Novara G, Ficarra V, Rosen RC, Artibani W, Costello A, Eastham JA, et al. Systematic review and meta-analysis of perioperative outcomes and complications after robot-assisted radical prostatectomy. Eur Urol. 2012;62(3):431–52.
8. Catalona WJ, Carvalhal GF, Mager DE, Smith DS. Potency, continence and complication rates in 1,870 consecutive radical retropubic prostatectomies. J Urol. 1999;162(2):433–8.
9. Lepor H, Nieder AM, Ferrandino MN. Intraoperative and postoperative complications of radical retropubic prostatectomy in a consecutive series of 1,000 cases. J Urol. 2001;166(5):1729–33.
10. Farnham SB, Webster TM, Herrell SD, Smith JA Jr. Intraoperative blood loss and transfusion requirements for robotic-assisted radical prostatectomy versus radical retropubic prostatectomy. Urology. 2006;67(2):360–3.
11. Tewari A, Srivasatava A, Menon M. A prospective comparison of radical retropubic and robot-assisted prostatectomy: experience in one institution. BJU Int. 2003;92(3):205–10.
12. Gandaglia G, Sammon JD, Chang SL, Choueiri TK, Hu JC, Karakiewicz PI, et al. Comparative effectiveness of robot-assisted and open radical prostatectomy in the postdissemination era. J Clin Oncol. 2014;32(14):1419–26.
13. Trinh QD, Sammon J, Sun M, Ravi P, Ghani KR, Bianchi M, et al. Perioperative outcomes of robot-assisted radical prostatectomy compared with open radical prostatectomy: results from the nationwide inpatient sample. Eur Urol. 2012;61(4):679–85.
14. Cole AP, Leow JJ, Chang SL, Chung BI, Meyer CP, Kibel AS, et al. Surgeon and hospital-level variation in the costs of robot-assisted radical prostatectomy. J Urol. 2016;196:1090.
15. Koc G, Tazeh NN, Joudi FN, Winfield HN, Tracy CR, Brown JA. Lower extremity neuropathies after robot-assisted laparoscopic prostatectomy on a split-leg table. J Endourol. 2012;26(8):1026–9.
16. Awad H, Walker CM, Shaikh M, Dimitrova GT, Abaza R, O'Hara J. Anesthetic considerations for robotic prostatectomy: a review of the literature. J Clin Anesth. 2012;24(6):494–504.
17. Siddiqui S, Bhandari A, Menon M. Complications of robotic prostatectomy. In: Hemal AK, Menon M, editors. Robotics in genito-urinary surgery. London: Springer; 2010. p. 377–90.
18. Demyttenaere S, Feldman LS, Fried GM. Effect of pneumoperitoneum on renal perfusion and function: a systematic review. Surg Endosc. 2007;21(2):152–60.
19. Awad H, Santilli S, Ohr M, Roth A, Yan W, Fernandez S, et al. The effects of steep trendelenburg positioning on intraocular pressure during robotic radical prostatectomy. Anesth Analg. 2009;109(2):473–8.
20. Weber ED, Colyer MH, Lesser RL, Subramanian PS. Posterior ischemic optic neuropathy after minimally invasive prostatectomy. J Neuroophthalmol. 2007;27(4):285–7.
21. Meininger D, Byhahn C, Wolfram M, Mierdl S, Kessler P, Westphal K. Prolonged intraperitoneal versus extraperitoneal insufflation of carbon dioxide in patients undergoing totally endoscopic robot-assisted radical prostatectomy. Surg Endosc. 2004;18(5):829–33.
22. Chandler JG, Corson SL, Way LW. Three spectra of laparoscopic entry access injuries. J Am Coll Surg. 2001;192(4):478–90. discussion 90-1
23. Hasson HM. Open laparoscopy: a report of 150 cases. J Reprod Med. 1974;12(6):234–8.
24. Larobina M, Nottle P. Complete evidence regarding major vascular injuries during laparoscopic access. Surg Laparosc Endosc Percutan Tech. 2005;15(3):119–23.
25. Ordon M, Eichel L, Landman J. Fundamentals of laparoscopic and robotic urologic surgery. In: Wein AJ, Kavoussi LR, Partin AW, Peters CA, editors. Campbell-Walsh urology. 1. 11th ed. Philadelphia, PA: Elsevier Saunders; 2015.
26. Ortega I. The Carter-Thomason needle suture passer to correct cannula-induced defects and vascular injuries in the abdominal wall during laparoscopy. J Am Assoc Gynecol Laparosc. 1996;3(4, Supplement):S37.
27. Antoniou SA, Antoniou GA, Koch OO, Pointner R, Granderath FA. Blunt versus bladed trocars in laparoscopic surgery: a systematic review and meta-analysis of randomized trials. Surg Endosc. 2013;27(7):2312–20.
28. van der Voort M, Heijnsdijk EA, Gouma DJ. Bowel injury as a complication of laparoscopy. Br J Surg. 2004;91(10):1253–8.
29. Novara G, Ficarra V, D'Elia C, Secco S, Cavalleri S, Artibani W. Prospective evaluation with standardised criteria for postoperative complications after robotic-assisted laparoscopic radical prostatectomy. Eur Urol. 2010;57(3):363–70.
30. Hu JC, Nelson RA, Wilson TG, Kawachi MH, Ramin SA, Lau C, et al. Perioperative complications

of laparoscopic and robotic assisted laparoscopic radical prostatectomy. J Urol. 2006;175(2):541–6. discussion 6
31. Murphy DG, Kerger M, Crowe H, Peters JS, Costello AJ. Operative details and oncological and functional outcome of robotic-assisted laparoscopic radical prostatectomy: 400 cases with a minimum of 12 months follow-up. Eur Urol. 2009;55(6):1358–66.
32. Guillonneau B, Gupta R, El Fettouh H, Cathelineau X, Baumert H, Vallancien G. Laparoscopic [correction of laproscopic] management of rectal injury during laparoscopic [correction of laproscopic] radical prostatectomy. J Urol. 2003;169(5):1694–6.
33. Katz R, Borkowski T, Hoznek A, Salomon L, de la Taille A, Abbou CC. Operative management of rectal injuries during laparoscopic radical prostatectomy. Urology. 2003;62(2):310–3.
34. Gonzalgo ML, Pavlovich CP, Trock BJ, Link RE, Sullivan W, Su LM. Classification and trends of perioperative morbidities following laparoscopic radical prostatectomy. J Urol. 2005;174(1):135–9. discussion 9
35. Cheon J, Orvieto MA, Patel VR. Key elements to approaching difficult cases in robotic urologic surgery. In: Patel VR, editor. Robotic urologic surgery. 2nd ed. London: Springer; 2012. p. 129.
36. Spaliviero M, Steinberg AP, Kaouk JH, Desai MM, Hammert WC, Gill IS. Laparoscopic injury and repair of obturator nerve during radical prostatectomy. Urology. 2004;64(5):1030.
37. Ficarra V, Novara G, Artibani W, Cestari A, Galfano A, Graefen M, et al. Retropubic, laparoscopic, and robot-assisted radical prostatectomy: a systematic review and cumulative analysis of comparative studies. Eur Urol. 2009;55(5):1037–63.
38. Bhayani SB, Pavlovich CP, Strup SE, Dahl DM, Landman J, Fabrizio MD, et al. Laparoscopic radical prostatectomy: a multi-institutional study of conversion to open surgery. Urology. 2004;63(1):99–102.
39. Tyritzis SI, Wallerstedt A, Steineck G, Nyberg T, Hugosson J, Bjartell A, et al. Thromboembolic complications in 3,544 patients undergoing radical prostatectomy with or without lymph node dissection. J Urol. 2015;193(1):117–25.
40. Montorsi F, Wilson TG, Rosen RC, Ahlering TE, Artibani W, Carroll PR, et al. Best practices in robot-assisted radical prostatectomy: recommendations of the Pasadena consensus panel. Eur Urol. 2012;62(3):368–81.
41. Secin FP, Jiborn T, Bjartell AS, Fournier G, Salomon L, Abbou CC, et al. Multi-institutional study of symptomatic deep venous thrombosis and pulmonary embolism in prostate cancer patients undergoing laparoscopic or robot-assisted laparoscopic radical prostatectomy. Eur Urol. 2008;53(1):134–45.
42. Orvieto MA, Coelho RF, Chauhan S, Palmer KJ, Rocco B, Patel VR. Incidence of lymphoceles after robot-assisted pelvic lymph node dissection. BJU Int. 2011;108(7):1185–90.
43. Feicke A, Baumgartner M, Talimi S, Schmid DM, Seifert HH, Muntener M, et al. Robotic-assisted laparoscopic extended pelvic lymph node dissection for prostate cancer: surgical technique and experience with the first 99 cases. Eur Urol. 2009;55(4):876–83.
44. Msezane LP, Reynolds WS, Gofrit ON, Shalhav AL, Zagaja GP, Zorn KC. Bladder neck contracture after robot-assisted laparoscopic radical prostatectomy: evaluation of incidence and risk factors and impact on urinary function. J Endourol. 2008;22(2):377–83.
45. Webb DR, Sethi K, Gee K. An analysis of the causes of bladder neck contracture after open and robot-assisted laparoscopic radical prostatectomy. BJU Int. 2009;103(7):957–63.
46. Fischer B, Engel N, Fehr JL, John H. Complications of robotic assisted radical prostatectomy. World J Urol. 2008;26(6):595–602.
47. Coelho RF, Palmer KJ, Rocco B, Moniz RR, Chauhan S, Orvieto MA, et al. Early complication rates in a single-surgeon series of 2500 robotic-assisted radical prostatectomies: report applying a standardized grading system. Eur Urol. 2010;57(6):945–52.